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'Gordon Creek'—A Superior, Tested Germplasm of Wyoming Big Sagebrush

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RESEARCH SUMMARY

This document establishes the basis for the release of 'Gordon Creek', a superior germplasm of big sagebrush. 'Gordon Creek' is an ecotype of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) collected near Helper, UT. This release is needed to increase nutrients in the winter diets of mule deer (*Odocoileus hemionus hemionus*) and sage grouse (*Centrocercus urophasianus*), and to restore disturbed lands. This sagebrush exceeds the typical winter forage values for energy, crude protein, phosphorus, and carotene. 'Gordon Creek' is adapted to drier sites than 'Hobble Creek', a previously released germplasm of mountain big sagebrush (*A.t.* ssp. *vaseyana*). Thirteen Wyoming big sagebrush germplasms were tested. 'Gordon Creek' was preferred by wintering mule deer and was eaten by wintering sage grouse.

'Gordon Creek' can be established and maintained over a wide geographic range on sites that have well-drained, deep or shallow soils with an average annual precipitation of 10 to 13 inches. Soil textures should not exceed 55 percent clay (sandy clay, silty clay, or clay). Soil pH may vary from 6.6 to 8.8.

'Gordon Creek' can be established by direct seeding on properly prepared seedbeds, by transplanting bareroot or containerized stock, or by a technique we term "mother plant."

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THE NEED

Mule deer (*Odocoileus hemionus hemionus*) winter diets are low in energy, protein, phosphorus, and carotene (Welch and others 1986). Big sagebrush (*Artemisia tridentata*) can help raise the nutrient levels of winter diets (Bhat and others 1990; Bunderson and others 1986; Welch 1989; Welch and Wagstaff 1992).

'Hobble Creek' mountain big sagebrush (*A.t.* ssp. *vaseyana*) was formally released in 1987 for commercial production. 'Hobble Creek' was targeted for use on mule deer and domestic sheep (*Ovis aries*) winter ranges with annual precipitation of at least 14 inches (Welch and others 1986). Recent studies show that sage grouse (*Centrocercus urophasianus*) and pronghorn (*Antilocapra americana*) also prefer 'Hobble Creek' (Welch and others 1991). Managers need a preferred big sagebrush like 'Hobble Creek' for revegetation to raise the nutrient levels of winter diets on shrublands having 10 to 13 inches of annual precipitation.

METHODS

The search for superior germplasms that could be used on shrublands with 10 to 13 inches of average annual precipitation centered on Wyoming big sagebrush. It has superior winter nutrient content and is adapted to dry sites (Welch and others 1986; Winward 1983). Thirteen geographically distinct populations were selected from locations listed in table 1. Seeds collected from each population will be referred to as germplasm.

After the seeds were collected, three test sites were chosen where all 13 germplasms could be raised in common gardens. These were located near Springville, UT; Glenns Ferry, ID; and Taylor Flats in Brown's Park, UT, about 12 miles east of Dutch John. Each site was mechanically cleared of native vegetation and surrounded by a deerproof fence. During the studies, deer could be allowed to graze on the plants by opening a 15-foot-wide gate. During the spring of 1987, containerized stock of the 13 germplasms was planted on the three test sites (Nelson 1984). Each germplasm was represented by 20 plants placed at random on a 7- by 7-foot grid. During the first growing season, plants received supplementary water at Brown's Park and Glenns Ferry.

Data collected were: height of plants after the first growing season (inches), length of current year's growth for the second, third, and fourth growing seasons (inches), wintering mule deer preference (percentage of current year's growth eaten), crude protein (percentage of dry matter), phosphorus content (percentage of dry matter), in vitro digestibility (percentage of dry matter digested during laboratory tests), and number of seedlings growing within 2.5 feet of the plants (Glenns Ferry only). The techniques used to collect the data have been described

Table 1—Acquisition sites (county and state) for germplasm of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)

Germplasms	County	State
GORDON CREEK	Carbon	Utah
Glenns Ferry	Elmore	Idaho
Brown's Park	Daggett	Utah
Oasis	Millard	Utah
Rush Valley	Utah	Utah
South Fredonia	Coconino	Arizona
Loa	Wayne	Utah
Squaw Butte	Harney	Oregon
Dinosaur	Moffat	Colorado
North Kemmerer	Lincoln	Wyoming
Warren	Carbon	Montana
Arco	Butte	Idaho
Daniel	Sublette	Wyoming

in the following publications: McArthur and Welch 1982 (growth), Welch and Wagstaff 1992 (preference), Welch and McArthur 1979 (crude protein), Welch and others 1988 (phosphorus), and Clary and others 1988 (in vitro digestibility).

Data were analyzed by one-way analysis of variance. If an analysis of variance produced an F-value significant at the 5 percent level, we used the least significant difference method to determine which treatment means were significantly different from one another (at the 5 percent level). Each of the 13 germplasms was considered to be a treatment, with the individual plants considered to be replications. Data of equal variances were pooled. These included: height of plants for first growing season (data pooled across sites), current year's growth for the second, third, and fourth growing seasons (data pooled across years within sites), wintering mule deer preference (data pooled across sites), and nutrient content (data pooled across sites).

RESULTS

Table 2 shows the height of plants at the end of the first growing season. Plants grown from 'Gordon Creek' germplasm averaged 6.4 inches tall, significantly taller than seven of the 13 germplasms tested. 'Gordon Creek' was not significantly shorter than any of the other germplasms tested. Table 3 shows the average of the current year's growth during the second, third, and fourth growing seasons. Due to unequal variances among test sites, data could not be pooled across sites. Years within a site

Table 2—Height of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) plants after one season of growth. Data from all three test sites were pooled. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Height of plants
	Inches
Oasis	6.5^{a}
GORDON CREEK	6.4^{a}
Rush Valley	6.4^{a}
South Fredonia	6.0^{ab}
Brown's Park	5.9^{ab}
Loa	5.8^{ab}
Squaw Butte	5.6^{bc}
Dinosaur	5.4^{bc}
Glenns Ferry	5.0^{cd}
North Kemmerer	4.9^{cde}
Warren	4.9^{cde}
Arco	4.6^{de}
Daniel	4.1^{e}

Table 3—Leader growth of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) grown on three different test sites. Data collected from the three test sites were not pooled. Data collected over three years within test sites were pooled. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Growth
	Inches
Springville Test Site	
South Fredonia	7.4^{a}
GORDON CREEK	6.8^{b}
Arco	6.4^{bc}
Squaw Butte	6.3^{bc}
Loa	6.2^{bc}
Warren	6.1^{bc}
Dinosaur	6.1^{bc}
Oasis	5.9^{cd}
Rush Valley	5.8^{cd}
Glenns Ferry	5.7^{cd}
Brown's Park	5.6^{cd}
North Kemmerer	5.2^{d}
Daniel	5.0^{d}
Glenns Ferry Test Site	
GORDON CREEK	3.4^{a}
Squaw Butte	3.2^{a}
South Fredonia	3.1^{ab}
Glenns Ferry	2.9^{abc}
Oasis	2.9^{abcd}
Loa	2.8^{abcde}
Warren	2.8^{bcde}
Brown's Park	2.8^{bcde}
Dinosaur	2.6^{bcde}
Arco	2.5^{cde}
Daniel	2.5^{cde}
North Kemmerer	2.4^{de}
Rush Valley	2.3^{e}
Brown's Park Test Site	
Loa	2.7
GORDON CREEK	2.6
South Fredonia	2.6
Glenns Ferry	2.5
Squaw Butte	2.5
Oasis	2.4
Rush Valley	2.4
Brown's Park	2.3
Dinosaur	2.3
Arco	2.2
Warren	2.1
North Kemmerer	2.0
Daniel	2.0

were pooled. Significant differences were detected among germplasms at the Springville and Glenns Ferry sites. 'Gordon Creek' was significantly more productive than six of the germplasms tested at Springville. Only South Fredonia germplasm was more productive there. At Glenns Ferry, the 'Gordon Creek' germplasm significantly exceeded seven other germplasms in growth. None of the other germplasms tested was significantly more productive. 'Gordon Creek' ranked second in growth at Brown's Park, but none of the differences there was significant. 'Gordon Creek' germplasm ranked among the most productive of the germplasms tested.

Preference

Table 4 shows the preference of wintering mule deer for the 13 germplasms of Wyoming big sagebrush. Because the Glenns Ferry test site had few deer, data were collected only from Springville and Brown's Park in Utah. Data collected from those sites were pooled. 'Gordon Creek' germplasm was significantly preferred by wintering mule deer (37.2 percent use) over all other germplasms. Mule deer heavily browse Wyoming big sagebrush at Gordon Creek where the germplasm was collected. Even during open winters when the deer could have moved to higher or lower elevations to feed, they still ate large quantities of the Wyoming big sagebrush there.

Table 4—Preference of wintering mule deer for 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) on the Springville and Brown's Park, UT, test sites. Data collected at the two test sites were pooled. Data are expressed as a percentage of the current year's growth removed. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Percent of growth used
GORDON CREEK	37.2^{a}
South Fredonia	23.8^{b}
Rush Valley	22.2^{bc}
Warren	18.8^{bcd}
Brown's Park	18.1^{bcd}
Daniel	16.3^{bcde}
Loa	15.8^{bcde}
Glenns Ferry	14.9^{bcde}
Squaw Butte	14.0^{bcde}
North Kemmerer	13.4^{cde}
Arco	12.3^{de}
Oasis	10.9^{de}
Dinosaur	7.8^{e}

Table 5—Winter crude protein content among 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) grown on three test sites. Data collected from the three test sites were pooled. Data are expressed as a percentage of dry matter. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Percent of crude protein
Daniel	13.9^{a}
North Kemmerer	13.5^{ab}
Squaw Butte	13.1^{ab}
Arco	13.1^{ab}
Oasis	12.8^{bc}
Rush Valley	12.5^{bc}
GORDON CREEK	11.9^{cd}
Warren	11.9^{cd}
Dinosaur	11.9^{cd}
Glenns Ferry	11.8^{d}
Brown's Park	11.7^{de}
Loa	11.3^{de}
South Fredonia	10.8^{e}

Nutrient Content

Table 5 shows the winter crude protein content of the 13 germplasms of Wyoming big sagebrush. Data collected from the three test sites were pooled. Four germplasms had a significantly higher crude protein content than 'Gordon Creek' (11.9 percent of dry matter). However winter crude protein levels of 'Gordon Creek' exceed the needs of wintering deer (Welch 1989) and the levels reported for many other shrubs, forbs, and grasses.

Table 6 shows the winter phosphorus content of the 13 germplasms. Data collected from the three test sites were pooled. No significant differences were detected among germplasms. 'Gordon Creek's winter phosphorus level was 0.21 percent of dry matter. This level just meets the needs of wintering deer (Welch 1989), but exceeds levels reported for some other shrubs, forbs, and grasses.

The results of the in vitro digestibility trials are shown in table 7. Data collected from the three test sites were pooled. 'Gordon Creek' digestibility (52.8 percent) was significantly exceeded by only one other germplasm (Arco, 56.6 percent). It significantly exceeded four germplasms and was not significantly different from the remaining eight. 'Gordon Creek' digestibility just meet the needs of wintering deer (Welch 1989), but exceeds the levels reported for many other shrubs and for some grasses and forbs.

Table 6—Winter phosphorus content of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Data collected from all three test sites were pooled. Data are expressed as a percentage of dry matter. There was no significant difference among germplasms or sites

Germplasms	Percent of phosphorus
Oasis	0.24
North Kemmerer	.23
Squaw Butte	.23
Arco	.23
Daniel	.22
Rush Valley	.22
Warren	.22
Loa	.22
GORDON CREEK	.21
South Fredonia	.21
Brown's Park	.21
Dinosaur	.21
Glenns Ferry	.21

'Gordon Creek' is clearly a superior germplasm of Wyoming big sagebrush for revegetating winter mule deer range, sage grouse habitat, and for restoring disturbed land. The key characteristics favoring its use were wintering deer preference and its high growth rate on all three test sites.

Table 7—Winter in vitro digestibility of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Data from all three test sites were pooled. Data are expressed as the percentage of dry matter digested. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Percent digested
Arco	56.6^{a}
Squaw Butte	55.1^{ab}
South Fredonia	53.7^{ab}
Warren	53.7^{abc}
GORDON CREEK	52.8^{bcd}
Oasis	51.7^{bcd}
Brown's Park	50.8^{cde}
Rush Valley	50.8^{cde}
Glenns Ferry	50.5^{cde}
Loa	50.4^{de}
North Kemmerer	50.1^{de}
Daniel	47.8^{e}
Dinosaur	47.7^{e}

SITE ADAPTATION

The native site of the 'Gordon Creek' germplasm is about 7 miles southwest of Helper, UT, at an elevation of about 6,000 feet. The average annual precipitation is about 12 inches. The average frost-free period is from 80 to 120 days. The soil is a Travessilla sandy loam. This is a shallow, well-drained soil derived predominantly from sandstone with a clay content of 10 to 18 percent. Effective rooting depth is between 7 and 20 inches. Soil reactions (pH) range from 7.4 to 8.8. Permeability is moderate with an available water capacity of 3 to 4 inches (Jensen and Borchert 1988; Utah State Engineer's Office 1931-60).

Glenns Ferry Site

The 'Gordon Creek' germplasm appears to be well adapted to the Glenns Ferry test site. Here 'Gordon Creek' produced 4.9 seedlings per live plant (table 8). It significantly exceeded seven other germplasms. Even the native Glenns Ferry germplasm did not have significantly more seeedlings. The growth of 'Gordon Creek' germplasm was among the highest recorded on this site (table 3). Elevation is about 3,800 feet. Average annual precipitation is about 11 inches. During the study period, however, the precipitation was 10 to 15 percent below average. The actual precipitation was probably from 9 to 10 inches. The soil is a silt loam of the Chilcott-Kunaton-Chardoton complex. This soil, derived

Table 8—Number of seedlings within 2.5 feet of 13 Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) germplasms grown at the Glenns Ferry test site. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Number of seedlings
Glenns Ferry	6.9^{a}
GORDON CREEK	4.9^{ab}
Brown's Park	3.4^{bc}
Squaw Butte	3.2^{bcd}
Dinosaur	2.9^{bcd}
Warren	2.6^{bcd}
Daniel	2.2^{cd}
Arco	1.6^{cd}
Rush Valley	1.5^{cd}
Loa	1.1^{cd}
Oasis	1.1^{cd}
South Fredonia	$.6^{d}$
North Kemmerer	$.5^{d}$

from loess and alluvium from various kinds of rocks is well drained. Effective rooting depth is from 20 to 30 inches. Soil reactions (pH) range from 6.6 to 8.4. Clay content ranges from 27 to 55 percent. Average frost-free period is about 110 days. Permeability is slow with available water capacity moderate (Noe 1991).

Springville Site

All 13 germplasms were adapted to the Springville test site, evidenced by high growth rates, high survival, and numerous long, branched seed stalks. All germplasms produced numerous seedlings. This site would be excellent for a seed increase garden. Elevation is about 5,000 feet. The average annual precipitation is about 16 inches. We measured 14.4 and 12.5 inches of precipitation for the 1988-89 and 1989-90 water years (author's data on file). The soil is a Pleasant Grove gravelly loam, a deep, well-drained soil derived from limestone, shale, and quartzite. Effective rooting depth is 5 feet or more. About 4 inches of available water is held by the soil to a depth of 5 feet. In summer, the soil can be dry to depths of 7 to 20 inches for more than 60 consecutive days. Soil reactions (pH) range from 7.4 to 7.9. Clay content ranges from 12 to 17 percent. The average frost-free period is about 160 days. Permeability ranges from 2.5 to 5.0 inches per hour (Swenson and others 1972).

Brown's Park Site

Due to heavy supplemental watering, it is difficult to judge the adaptation of 'Gordon Creek' germplasm to the Brown's Park site. Precipitation during the study period was just 60 to 70 percent of the 8- to 10-inch average annual precipitation. Although we believe 'Gordon Creek' would have survived the drought, supplemental watering was needed to produce enough current year's growth for the mule deer preference studies. Elevation at this site is 5,700 feet. The soil is an Abra sandy loam, a deep, well-drained soil derived from sedimentary and metamorphic rocks of the Brown's Park Formation and Mancos Shale. The effective rooting depth is 5 feet. Soil reactions (pH) range from 7.9 to 8.4. The clay content ranges from 7 to 26 percent. Average frost-free period is about 120 days. Permeability is moderate (author's data on file).

'Gordon Creek' Wyoming big sagebrush germplasm appears to be widely adapted and can be grown on sites with the following physical characteristics:

1. Mean annual precipitation of 10 to 13 inches.
2. Deep to shallow, well-drained soils.
3. Clay content up to 55 percent.
4. Soil pH between 6.6 and 8.8.
5. Growing season of at least 80 days.

ESTABLISHMENT METHODS

'Gordon Creek' big sagebrush can be established on suitable sites by direct seeding, by transplanting bareroot or containerized stock, or by a technique we term "mother plant." Descriptions of these techniques follow.

Direct Seeding

Direct seeding is the most practical method for establishing 'Gordon Creek' on areas larger than 10 acres. A successful direct-seeding program starts with high-quality, certified seed. Commercial sources of certified 'Gordon Creek' seed will be available by January 1994. Techniques have been developed to cost effectively clean the seed to a pure live seed content of 40 to 60 percent. This will greatly reduce the cost of shipping, handling, and storage. Storage life of big sagebrush seed in an open warehouse without temperature or humidity controls is about 5 years (Stevens and others 1981). If the seed analysis is over 1 year old, seedlots should be tested for germination before being used in a direct seeding program.

After a suitable site has been chosen, the next step is site preparation. This usually means total or partial removal of existing vegetation to reduce competition. Vegetation can be cleared by fire, machinery, or herbicides. The amount of vegetation removed will depend on the amount and kinds of other forage species seeded with 'Gordon Creek' big sagebrush. We recommend planting 'Gordon Creek' with other forage species because mixtures are more productive than monocultures, mixtures extend the season of use, and mixtures are more resistant to diseases and insects. 'Gordon Creek' should be sowed at the rate of one-eighth to one-fourth pound of pure live seed per acre.

The timing and depth of seeding are critical. On the native site, 'Gordon Creek' seed is dispersed by wind during early December. Therefore, we believe the best time to sow the seed is just before snow accumulation (Young and Evans 1986). For a mixture, the optimum planting depth will depend on the different species included. 'Gordon Creek' seed should be sown on a **firm** seedbed at or near the surface. In greenhouse studies, almost no seedlings emerged when big sagebrush seeds were planted deeper than three-sixteenths inch (Jacobson and Welch 1986). Frost heaving and the expansion and contraction of the soil surface by wetting and drying will cover the sagebrush seed enough so it will germinate and establish itself.

'Gordon Creek' seed can be sown by aerial seeders, cyclone seeders, dribblers, or drills that have been adjusted to leave the seeds on the surface. When using a drill, Richardson and others (1986) recommend that sagebrush and other shrubs be planted in different rows than grasses and forbs. Because grasses and forbs develop more quickly, they may keep shrubs from becoming established. This planting technique also requires less shrub seed. Competition within the seed mixture is apparently not as much of a problem when seed is sown aerially or broadcast onto a prepared **firm** seedbed. The more diverse microhabitats available for seed placement apparently reduce competition (Young and Evans 1986).

Transplanting Bareroot and Containerized Stock

Expense limits the usefulness of transplanting bareroot or containerized stock to small, critical areas, or to seed increase gardens or demonstration plots. Planting stock should be at least 5 to 8 inches tall, overwintered in an unheated nursery bed or lathhouse. The stock can be transplanted as soon as the soil can be tilled in the spring. We recommend transplanting properly hardened stock in early spring. However, containerized stock can be successfully transplanted in the summer if it receives adequate irrigation during the first growing season.

For each transplant, an area of from 0.5 to 1 square foot must be cleared of all competing plants. This can be done by mixing the soil and killing tops, roots, stolons, and rhizomes of competing species with a shovel. Soil must be packed firmly around the transplant's entire root system. To enhance survival and growth, a 1- to 3-inch deep basin should be constructed around the stem to catch water. In extremely dry areas or during dry periods, the basin can be filled with water. For containerized stock, the growing medium should be covered with 0.5 inch of soil. This prevents the growing medium from acting as a wick and drying out the transplant. First year survival rates should be 80 percent or higher.

"Mother Plant"

This technique combines transplanting and natural seed dispersal. Shrubs established by transplanting can serve as mother plants to produce seeds for dispersal. This technique can be used after a fire or some other disturbance has destroyed a native sagebrush stand. The reduction or absence of the native stand's residual seed enhances the opportunity to establish a superior germplasm with this technique. The mother plants are planted as containerized or bareroot stock on a 50- by 50-foot grid throughout the site. Successful establishment and growth of the mother plants may require the plants to be individually fertilized, irrigated, fenced, or otherwise cared for.

After 3 to 5 years, the mother plants should produce seed. Competing vegetation can be cleared in strips or in spots around the mother plants using machinery or herbicides. This technique can help maintain big sagebrush stands that receive heavy use year after year (Wagstaff and Welch 1990). Heavy grazing may reduce seed stalk (and hence seed) production to one-thirtieth or one-fiftieth of normal (Wagstaff and Welch 1991).

CONCLUSIONS

'Gordon Creek' is a superior Wyoming big sagebrush germplasm for revegetating mule deer range, sage grouse habitat, and for restoring disturbed lands. It was preferred by wintering deer and had a high growth rate on all three test sites. It can raise the level of energy, protein, phosphorus, and carotene in the diet of a number of wintering animals.

'Gordon Creek' big sagebrush can be established by several techniques. It appears to be widely adapted and can be grown on sites with the following physical characteristics:

1. Mean annual precipitation of at least 10 inches.
2. Deep to shallow, well-drained soils.
3. Clay content up to 55 percent.
4. Soil pH between 6.6 and 8.8.
5. Growing season of at least 80 days.

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Welch, Bruce L.; Nelson, E. Dwain; Young, Stanford A.; Sands, Alan R.; Wagstaff, Fred J.; Nelson, David L. 1992. 'Gordon Creek'—a superior, tested germplasm of Wyoming big sagebrush. Res. Pap. INT-461. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 7 p.

A superior germplasm of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) has been evaluated for revegetating mule deer winter ranges and sage grouse habitats, and restoring disturbed lands. This germplasm, 'Gordon Creek', can increase the level of energy, protein, phosphorus, and carotene in the diet of wintering mule deer. 'Gordon Creek' is adapted to drier sites than 'Hobble Creek', a previously released germplasm of mountain big sagebrush. We describe the need for the germplasm, its nutrient content, areas of adaptation, and procedures for establishing it.

KEYWORDS: preference, winter range, nutritive value, establishment, revegetation, *Artemisia tridentata*, mule deer, sage grouse, rehabilitation, browse plants

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